previous experience, which shows that, as a rule, when a "sudden commencement" occurs not far from noon of local time the principal maxima and minima of the storm occur within the next twelve or fifteen hours, but that if the "sudden commencement" occurs late in the day the full development of the disturbance is postponed until the *post-meridiem* hours of the following day.

The changes in the horizontal components of force throughout the disturbance were on a very large scale, and took place with a rapidity so great that the photographic traces are in some parts too faint to read. But the most unusual feature of the storm was the remarkable series of changes in the value of the vertical component of force. In most magnetic storms the general course of events comprises (1) a gradual increase in V to a maximum (in some cases two successive maxima) reached about 18h. local time, (2) a gradual fall until midnight, (3) a rapid fall to a minimum which is reached about 1h., (4) a gradual recovery to nearly the undisturbed value, which recovery is completed by about 8h., and is sometimes accompanied by (5) a series of short-period pulsations. The whole sequence is frequently repeated on a modified scale later on in the second day. In the storms now described this course of events was followed so far as the first twenty-four hours are concerned. The first maximum on May 13 was reached at 20h. 37m., and was 152γ above the undisturbed value at the time of the "sudden commencement." One or two falls in value succeeded until 21h. 24m., when a rapid fall of more than 350γ in six minutes carried the light spot off the paper. The principal minimum which then occurred took place at an unusually early hour (see "British Meteorological and Magnetic Yearbook," 1915, part iv., p. 89, and plate vi.). According to the theory which would account for magnetic storm phenomena by assigning them to the earth's rotation in a beam of particles emanating from the sun, this sudden drop in the value of V might be supposed to take place at or soon after midnight of local time, but not so early as 9 p.m. The rate of change in V during the descent to the minimum referred to was large, but by no means the largest recorded at Eskdalemuir. For example, the storm of March 23, 1920, showed a case of V changing at the rate of 169γ per minute. The gradual recovery which followed the minimum was accompanied, particularly between 6h. and 8h., by pulsations of about four minutes' period and of amplitude averaging about 4γ. It is, perhaps, unsafe to generalise, but there is some evidence to show that such pulsations in vertical force do not occur in a magnetic storm unless the total range of disturbance in V exceeds a certain amount.

The second twenty-four hours of the storm showed even more remarkable developments than the first. After several maxima and minima had been passed the value of V began to fall about 23h. on May 14, and the light spot went off the paper at midnight. Between 1h. and 6h. on May 15 at least a dozen extensive and rapid changes in V took place, swinging the light spot alternately beyond the upper and below the lower edge of the paper. The most clearly marked of these occurred between 2h. 40m. and 2h. 44m. on May 15, and involved a change during that interval at the rate of 138γ per minute. Repeated oscillations of this character and magnitude have not hitherto been recorded at Eskdalemuir. The course of the disturbance during May 16 was remarkable in that the fall in the value of V during the early hours of the morning continued until nearly 7h.

The storm had practically died down by noon on May 17, but soon after 23h. on that day another "sudden commencement" was recorded, and the sheet which will be taken off the recording drums to-morrow morning will probably show a recurrence of disturbance.

A. CRICHTON MITCHELL.

Eskdalemuir Observatory, May 18.

Ocean Tides.

THE article in NATURE of March 10, p 33, on oceanographic problems by "J. J." prompts one interested in tides to direct attention to the services which a new *Challenger* expedition might render to the general theory of ocean tides at relatively little cost either in time or in money.

There are numerous localities for which tidal information is either inadequate or wholly lacking. Sir George Darwin directed attention to some of these places by publishing in the *Geographical Journal* of November, 1909, a memorandum prepared by the late Dr. R. A. Harris, of the U.S. Coast and Geodetic Survey. The "dozen or so landing parties placed here and there over the world" suggested by "J. J." could undoubtedly use to advantage as their bases of operations some of these places for which tidal observations are needed. These suggested landing parties could therefore, in connection with their other observations, secure tidal data of great value.

It may not, perhaps, be amiss here to point out that such tidal observations would serve two important purposes. In the first place, they would increase our geographical knowledge of the regional distribution and local characteristics of the tides; and in the second, they would furnish further data of an accurate character to test the merits of the various tidal theories that attempt to interpret mathematically the terrestrial phenomena of the tides. Thus some of the places for which tidal information is desired are of critical importance to the so-called "stationary wave" theory of tides, which appears steadily to be gaining in favour.

The use of automatic or self-recording tide gauges would, of course, be most desirable. In this connection it is to be noted that such tide gauges may now be had in small and inexpensive types that require no elaborate installation and may be expeditiously set up. It cannot, however, be too strongly emphasised that valuable additions to our knowledge of the tides at out-of-the-way or infrequently visited places may be secured by recording hourly the height of the tide as registered on a naked tide-staff graduated to feet and tenths. The longer the series of observations, the better; but even a day or two will furnish considerable information.

The value of the tidal observations would be greatly enhanced if bench-marks of a permanent character were established and the relation of the zero of the tide-staff to these bench-marks determined. This would make possible correlation with any future tidal observations at the same places, and might even permit a quantitative determination of the local rate of elevation or subsidence of the land relative to the sea.

A fertile and almost virgin field is offered to the investigators of a new *Challenger* expedition in the study of the tides of the open sea, the importance of which is obvious. Several forms of automatic tide gauges adapted for offshore tidal observations appear to have given satisfactory service. Recently an offshore hydrographic party secured an excellent series of tidal observations by means of an improvised tide gauge consisting of a graduated tide-staff secured to a float and confined in a float-tube made up of sections of 2-in. pipe, the lowest section of which was cast into a block of cement. It also appears that satis-

© 1921 Nature Publishing Group

factory results may be obtained by means of a sounding wire attached to a heavy block of concrete or box of stones (see *Science*, vol. xlii., 1904, p. 704).

Those members of the new *Challenger* expedition whom fortune may choose to be responsible for the tidal observations have it in their hands to make all tidal workers using their data everlastingly grateful. This gratitude they may secure by insisting that the tidal observations should be made in Greenwich mean civil time, reckoning the hours from 0 to 23. Apart from the many advantages for purposes of computation resulting from such procedure and the ease with which time comparisons of the tide at different places may be made, there is one outstanding advantage—it will remove all uncertainty as to the kind of time used. Many otherwise excellent tidal observations are of little use because there is no certainty as to the kind of time employed, whether mean local civil, mean local astronomical, local apparent or standard time for some unknown meridian. The use of Greenwich mean civil time should prove further desirable in view of the change to this kind of time soon to be made in the Nautical Almanac published by the British Admiralty.

H. A. Marmer.

U.S. Coast and Geodetic Survey, Washington, D.C., April 15.

The Physical Status of "Space."

To answer all Mr. Bonacina's points (Nature, May 5, p. 300) is not possible in a single letter. I agree with him that no rigid boundary can be drawn between the provinces of the older physics and metaphysics. Concepts are freely introduced into both which are not known to experience, and are never used either in describing past experience or in inferring future experience. Some hypotheses are necessary in any science, but hypotheses that are never used are neither necessary nor useful. The elastic solid æther forms an excellent example of these. It is assumed that electric and magnetic forces satisfy certain differential equations, and this is the only assumption required for the theory of the propagation of electromagnetic waves. The æther theory, however, introduces the additional hypothesis that one of these forces is a displacement in an elastic solid the properties of which differ from those of any ordinary solid. This assumption is never used, has no basis in experience, and cannot be tested experimentally. Accordingly I say it should not be made, for the introduction of additional hypotheses decreases the probability of the theory. The other assumption, which is valuable and leads to much new knowledge, makes no mention of an æther. It appears to be the case that all so-called explanations of physical laws by means of the æther are really based on some mathematical assumption that makes no reference to an æther at all.

I cannot see Mr. Bonacina's difficulty about "empty space." I have advanced no theory involving any such entity, and think that space is as useless a concept in physics as æther. To construct a space with suitable properties may be an aim of physics, but it is certainly not the starting point. The existence of entities incapable of being objects of experience is a thorny problem even to metaphysicians, and I think that physicists would do well to postpone its consideration so far as possible until they have some idea of the basis in their knowledge of the propositions to which they attach high probabilities.

Dr. Campbell's point (May 5, p. 301) is dealt with in the article (Nature, February 17) of which I was part author. Geometry is *not* the measurement of the earth, and never was; it was pointed out in the article that that excellent idea in nomenclature was never carried out. Euclid's geometry was, from the nature of its constructions and postulates, quite inapplicable to earth measurement. If anyone doubts this, let him consider the definitions and axioms as they stand and see how many of them are verifiable in even a few cases on a scale such as occurs in surveying. Further, Euclid's treatment assumes that the postulates are true in all cases. To suggest that this can be known by experiment is ridiculous. It is at best an inference to which a high probability can be attached. I know of nobody but Einstein and his followers who has used the word "geometry" in any other than the mathematical sense. The measurement of the earth is always known as "geodesy," and has been for more than a century; and measurement in general is "mensuration," the most important and least discussed of all sciences. Constancy in terminology requires that these meanings should be retained. Dr. Campbell would scarcely claim that measurement in general should be called "geometry" in *his* sense.

Harold Jeffreys.

The Reparation Act and Scientific Research.

Prof. Gardiner (Nature, May 19, p. 359) is one of many British men of science who are helping to pay the German war indemnity. One does not obtain goods from Germany unless one is compelled; it is difficult to see how standard German books and new publications can be procured from home industries, and they are necessary to research. In other cases the goods might be expected to be made by British firms. For many months I have been trying to obtain Wollaston wire of a certain diameter from a well-known British firm. At first I was informed that it could not possibly be made. I had bought it before in Germany, so they tried to make it. Several samples were unsatisfactory, and finally I was told that the British firm did not wish to make any further attempts. I then ordered some of the German wire, which I was required to pay for in advance, for the reason stated by Prof. Gardiner. This was reasonable, as the price charged by the German firm, *plus* indemnity which I pay, is less than I have been paying for unsatisfactory wire in England. The wire was on the way for several weeks. Meanwhile work was delayed. The Customs officials know nothing of the reduction of the tax from 100 per cent. to 26 per cent., announced by Mr. Chamberlain. Another order for new books, given in February, was dispatched from Bonn on March 4, and arrived in London on April 12 and April 16. Notice from the Customs was received a month later. After two days spent at the Customs filling up forms, and five letters requesting delivery, I still await the latter.

The condition of the British man of science who elects to do research will soon become impossible. Perhaps that is really the idea behind all this. The extension of the "key industry" idea will finish us altogether.

J. R. Partington.

East London College, University of London, May 20.

The Resonance Theory of Hearing.

I should like, in the first place, to take this opportunity of thanking Dr. Perrett for his reply in Nature of May 5 (p. 301), but I feel difficulty in accepting the explanation he there advances on the displacement hypothesis, because it does not seem to me to fit in

© 1921 Nature Publishing Group